Final Report

High Resolution Solar Radiation Data for Biogenic Emissions Modeling for 2002 Ozone Episodes in the Houston Area

Work Order No. 17
TNRCC Umbrella Contract No. 31984

Prepared for:

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Abstract

The purpose of this work assignment was to produce high-resolution data on shortwave radiation, photosynthetically active radiation (PAR) and cloud cover at hourly time intervals, for three high ozone periods in the Houston area. The episode dates were August 22-September 2, 2000, August 15-21, 2000 and September 3-18, 2000. The geographic area of interest is the Houston/Galveston and Beaumont/Port-Arthur ozone non-attainment areas comprided of Harris, Galveston, Brazoria, Fort Bend, Liberty, Chambers, Montgomery, Waller, Hardin, Jefferson and Orange counties. The data are required to support of the development of a biogenic emission inventory for the Houston/Galveston (H/G) area by the Texas Natural Resource Conservation Commission (TNRCC). This report describes the development of the high-resolution solar radiation data, appropriate support information, and a discussion of the data sources, analysis and QA procedures.

The data, graphics, and files used in the preparation of this document and needed to document the results and conclusions are included on a CD-ROM, enclosed.

1. Introduction

The Texas Natural Resource Conservation Commission (TNRCC) is responsible for developing an emissions control plan for the Houston/Galveston (H/G) area to bring the area into compliance with ozone air quality standards. Emissions from natural sources are important to the photochemistry of the lower atmosphere. In particular, emissions from plants and soils (biogenic emissions) are precursors to the formation of tropospheric ozone. Information on photosynthetically active radiation (PAR) is needed as input to the biogenic emissions inventory.

The University of Maryland developed methods for deriving PAR data from observations made from the geostationary satellite GOES-8. The methodology is currently implemented operationally for NOAA/NESDIS (http://www.nesdis.noaa.gov) at 0.5-degree resolution and hourly time intervals. The PAR inputs for biogenic emissions modeling are required at higher spatial resolution than currently available. The Department of Meteorology, University of Maryland, is developing capabilities to reprocess several years of satellite data with improved cloud detection methods. Under this project, capabilities were developed to produce high resolution surface radiative fluxes and cloud amounts using the inference scheme used to produce the NOAA/NESDIS operational product, as distributed to the users in support of the GEWEX Continental–scale International Project (GCIP) activity, via:

http://metosrv2.umd.edu/~srb/gcip/gcipsrb.htm

The coupling of the operational model to satellite data as implemented at NOAA/NESDIS, requires cloud screening and data gridding at 0.5-degree. The original satellite input data are discarded at NOAA after the model is run; only the processed cloud information is stored. Since the saved cloud products are gridded to 0.5-degree resolution, any subsequent runs would be restricted to this resolution, and no modification to cloud processing would be possible. To obtain information at a higher

spatial resolution requires availability of the original satellite data, and development of new interfaces between the model and data.

A five-channel algorithm for cloud screening (internally known as Version 3.0) has been implemented at the University of Maryland and applied experimentally at 0.5-degree resolution. This version of cloud screening has been used to prepare inputs for producing the high-resolution products for biogenic emission modeling.

Cloud Screening Algorithm

For producing radiative fluxes over the Texas region for the 2000 ozone episode, Version 1.4 of the cloud screening model was used. Versions 1.4 and 3.0 differ only during the snow season. Version 1.4 is applicable only during snow free periods, while version 3.0 has an additional component that allows cloud detection over snow. During the snow free season, these two versions are the same. Use of the Version 1.4 algorithm in this study will have no adverse impact on the results developed for Texas in the summer of 2000.

2. Work Accomplished

2.1 Input and Output Information

Goes-8 satellite data in five channels, at highest available resolution were obtained for use in this study. They were available from independent sources in the McIdas format. For this work the SW, PAR and cloud amount data that are produced from the inference scheme are at 1/8th of a degree, for the entire United States, and at 1/16th for an extended area over Texas, that includes the primary areas of interest: the Houston/Galveston and Beaumont/Port-Arthur ozone non-attainment areas (Harris, Galveston, Brazoria, Fort Bend, Liberty, Chambers, Montgomery, Waller, Hardin, Jefferson and Orange counties) as well as the area of East Texas covering Houston, Corpus Christi, Dallas and

Longview. Data were developed for the time periods August 22-September 2, 2000; August 15-21, 2000; and September 3-18, 2000, ozone episodes, according to the tasks described below.

Data were prepared in the "Little Endian" binary format and instructions were prepared to transfer the data into formats compatible with the TNRCCs Unix computers (SGI and IBM) in IEEE "Big Endian" binary format. To read the data on a **Big Endian** machine, the bytes must be swapped around the middle. Some FORTRAN compilers have an option for doing the conversion between the two formats. Alternatively, the Fortran program (read_d_bigend.f) can be used. This is a **Big Endian** version of read_d.f that includes a subroutine to swap the bytes. The sample code assumes that the record length is given in 4-byte words. If your compiler requires bytes for the record length, you should uncomment the line "Lrec=4 *

2.2 Methodology

Data were processed using an improved cloud screening methodology for inferring model cloud input parameters, using the available GOES-8 4 km data. The following procedure was followed:

1. Prepared the satellite data base for the selected periods.
2. Prepared information on precipitable water, for input to model.
3. Gridded the precipitable water available at 0.5 degree resolution into 1/8th and 1/16th resolution grids.
4. Stratospheric ozone was obtained from climatology.
5. The cloud screening algorithm was run for the designated region and selected time period; 4 types of pixels are obtained from this procedure:

a. clear
b. cloudy
c. clear mixed
d. clear cloudy

A procedure has been developed to allocate the mixed categories into clear and cloudy; **Version 3.0** of this procedure was applied here.

6. Processed the satellite data into cloud parameters, as required by the inference scheme.
7. Ran the inference scheme (this is usually done after the cloud parameters are gridded at 0.5 degree). This required building a new interface to the higher resolution data.
8. The products were instantaneous satellite estimates at selected resolutions. These values were integrated, to obtain hourly averaged data.

3. Deliverables

The data were provided to the TNRCC as soon as they were completed on CD-ROM, one for each of the three episode periods. The same data are collected together and included as an electronic appendix to this report on a single CD-ROM. The data are organized into directories for each period called P1, P2 and P3. For each period, there are two sub-directories:

1) par-8
2) par-16

The first one includes the results at 1/8th degree resolution, while the other includes the 1/16th degree resolution data. Graphical displays of model outputs are included for both resolutions.

3.1 Detailed description of the CD ROMs

On the CD ROMs are two directories. One (deg1_8) contains the 1/8 degree PAR, SW, and cloud amount data for the entire United States for the periods August 22 to September 1, 2000. The other (deg1_16) contains the 1/16 degree PAR, SW, and cloud amount for the extended Texas area. Both directories include selected figures, so the user can test if the data are read correctly. A separate readme file is provided for each subdirectory.

Period 1: August 22-September 2, 2000

For this period, the CD-ROM provides satellite estimates of PAR, Shortwave (SW) downward radiation and cloud amount at 1/8th of a degree resolution. The data are provided as instantaneous, hourly and daily values. The cloud amount is given only as an instantaneous value at the nominal time of observations about 15 minutes past the hour. The floating point binary data conform to the little endian specification, and were written on a DEC workstation. To read the data on a big endian machine, instructions were prepared and placed at the web site:

http://metosrv2.umd.edu/~srb/gcip/faq.htm

Filenames:

instantaneous: yymm***.i
hourly: yymm***.h
daily: yymm***.d

Where:

yy: year (two digits)

mm: month (two digits)

par: photosynthetically active radiation

sda: Shortwave downward

ccf: cloud amount

File Structure

Data for the parameter par at instantaneous, hourly and daily time resolutions for the time period August 22 to September 1, 2000 are contained in a single file. Hourly averaged files contain all 24 hours for a day, and all days for the specified time period, even if data are missing. The hours for the hourly average files are local standard time (1-24). For August 2000, there are 10 days included in the file. For September 2000, there is 1 day (Sep. 1) included in the file. Use the GrADS data descriptor files, 0008parh.ctl, 0008pari.ctl, 0008pard.ctl, 0009pard.ctl, 0009parh.ctl, 0009pari.ctl, 0008sdah.ctl, 0008sdad.ctl, 0008sdai.ctl, 0009sdad.ctl, 0009sdah.ctl, 0009sdai.ctl, 0009ccfi.ctl to view the data under GrADS interface. Fluxes are given in Wm-2 and missing data are represented by -999.

Grid Structure

Each file has information for 88641 (0.125 by 0.125 degree, equal-angle) cells (441 latitudes and 201 longitudes). All cells are present, even when data are missing. The cells are written sequentially, proceeding eastward through the latitude zone, then northward to the next latitude zone. The center lat/lon coordinates of the first cell are 25 N, 125 W, and those of the last cell are 50 N, 70 W.

The FORTRAN code cread_h.f code reads hourly data, cread_d.f reads daily data, and cread_i.f reads instantaneous data. The Unix command "gzip -d filename" should be used for uncompressing data

List of Images

Two sets of images are provided in gif format. The file naming convention is described below and examples are shown in Figures 1 and 2.

1. YYMMDD_par_d_deg1_8_ver3.0.gif

Daily mean surface downward PAR at 1/8th of a degree resolution.

2. compYYMMDDHH_par_i_ver3.0.gif:

Upper panel: instantaneous surface downward PAR at 1/16th of a degree resolution;

Lower panel: Corresponding data at 1/8th of a degree resolution

Where:

YY: year
MM: month
DD: day
HH: hour

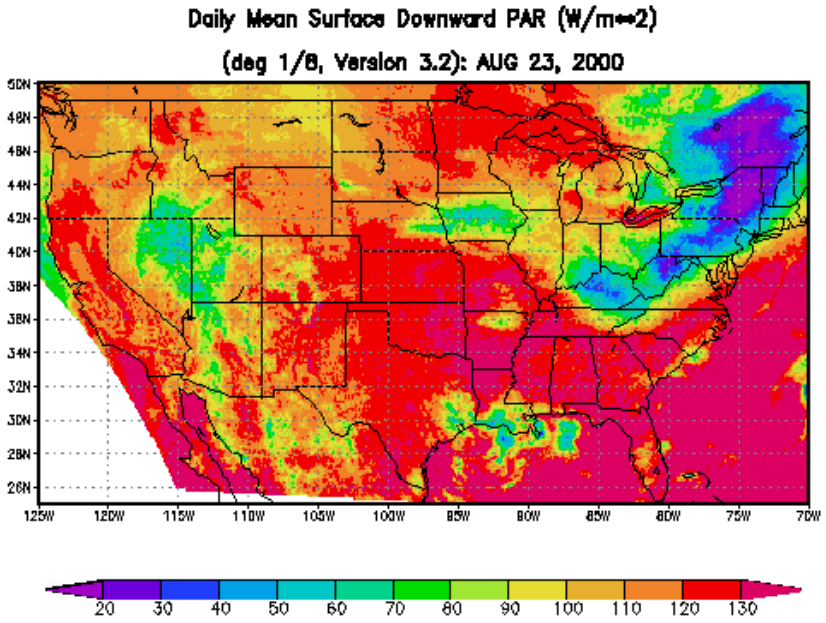

Figure 1. Daily mean surface downward PAR at 1/8th of a degree resolution for August 23, 2000.

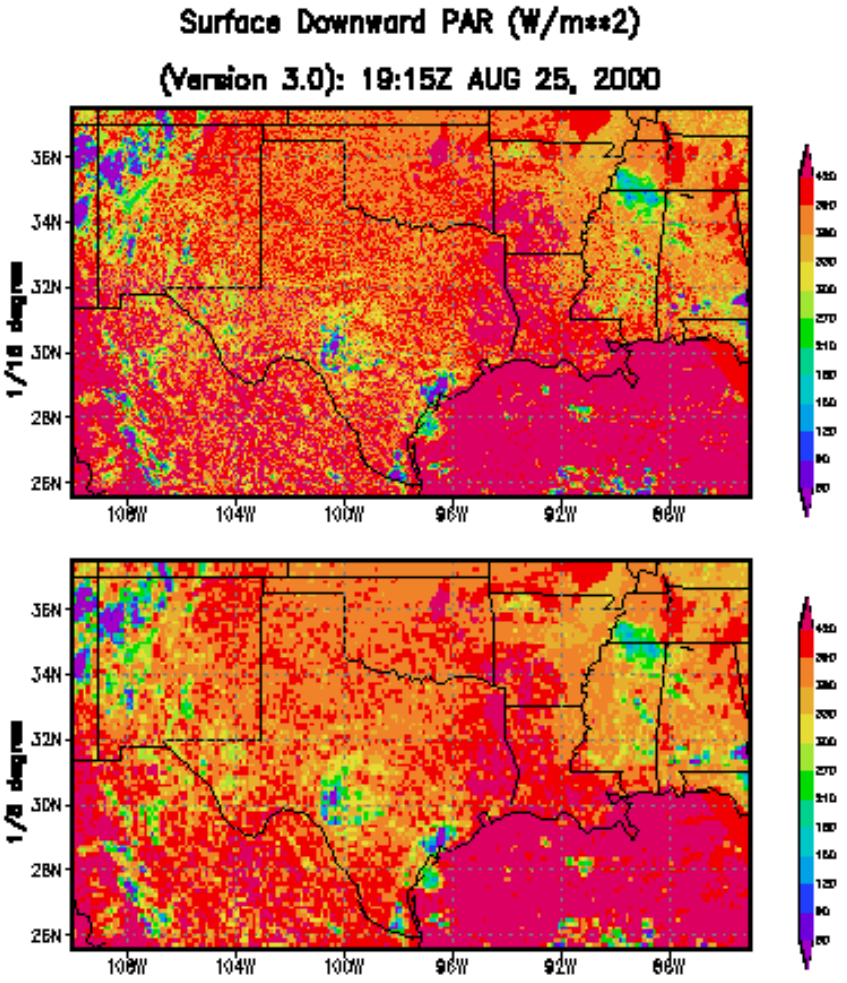

Figure 2. Comparison of instantaneous surface downward PAR at 1/16th and 1/8th degree resolution on August 25, 2000.

Period 2: August 15-21, 2000

There are two directories. One (deg1_8) contains the 1/8 degree PAR, SW, and cloud amount data for the entire United States for the periods August 15 to August 21, 2000. The other (deg1_16) contains the 1/16 degree PAR, SW, and cloud amount for the extended Texas area. Both directories include selected figures, so the user can test if the data were read correctly. A separate readme file is provided for each subdirectory. The rest is similar to the first period.

Period 3: September 3-18, 2000

There are two directories. One (deg1_8) contains the 1/8 degree PAR, SW, and cloud amount data for the entire United States for the periods September 2 to September 18, 2000. The other (deg1_16) contains the 1/16 degree PAR, SW, and cloud amount for the extended Texas area. Both directories include selected figures, so the user can test if the data were read correctly. A separate readme file is provided for each subdirectory. The rest is similar to the first period.

4. Quality Control

The routinely produced satellite-based estimates of the surface SW fluxes at 0.5 degree resolution are evaluated against ground truth as available from projects, such as **SURFRAD** the DOE Atmospheric Radiation Measurement **ARM/CART/SGP** observations obtained from the central facility (36.605° N, 97.485° W), the AZMET network and the Illinois State Water Survey. The data produced under this project have been evaluated against ground observations as available from the **SURFRAD** network. Selected results are being enclosed here.

1. Comparison of hourly satellite estimates and observed surface SW downward fluxes for 08/2000 (Version 3.0), at 1/8 degree. Figure 3 (top).

2. Same as above for daily values. Figure 4.

3. Same as above for monthly three hourly mean values. Figure 6.

4. Comparison of hourly satellite estimates and observed surface SW downward fluxes for 09/2000 (Version 3.0), at 1/8 degree. Figure 3 (bottom).

5. Same as above for daily values. Figure 5.

6. Same as above for monthly three hourly mean values. Figure 7.

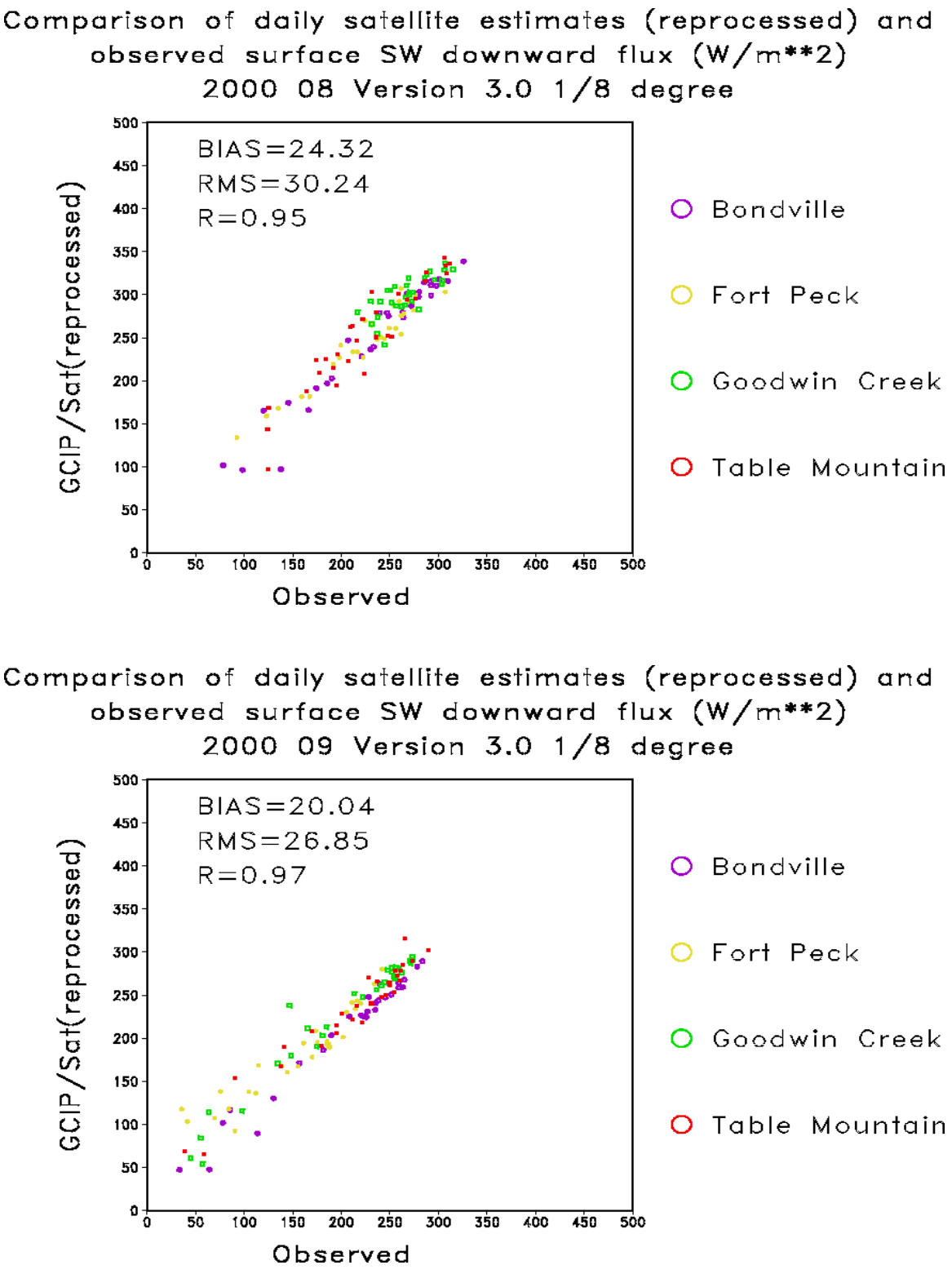

Figure 3. Comparison of daily average satellite estimated and observed surface downward SW flux for August 2000 (top) and September 2000 (bottom) at four SURFRAD sites.

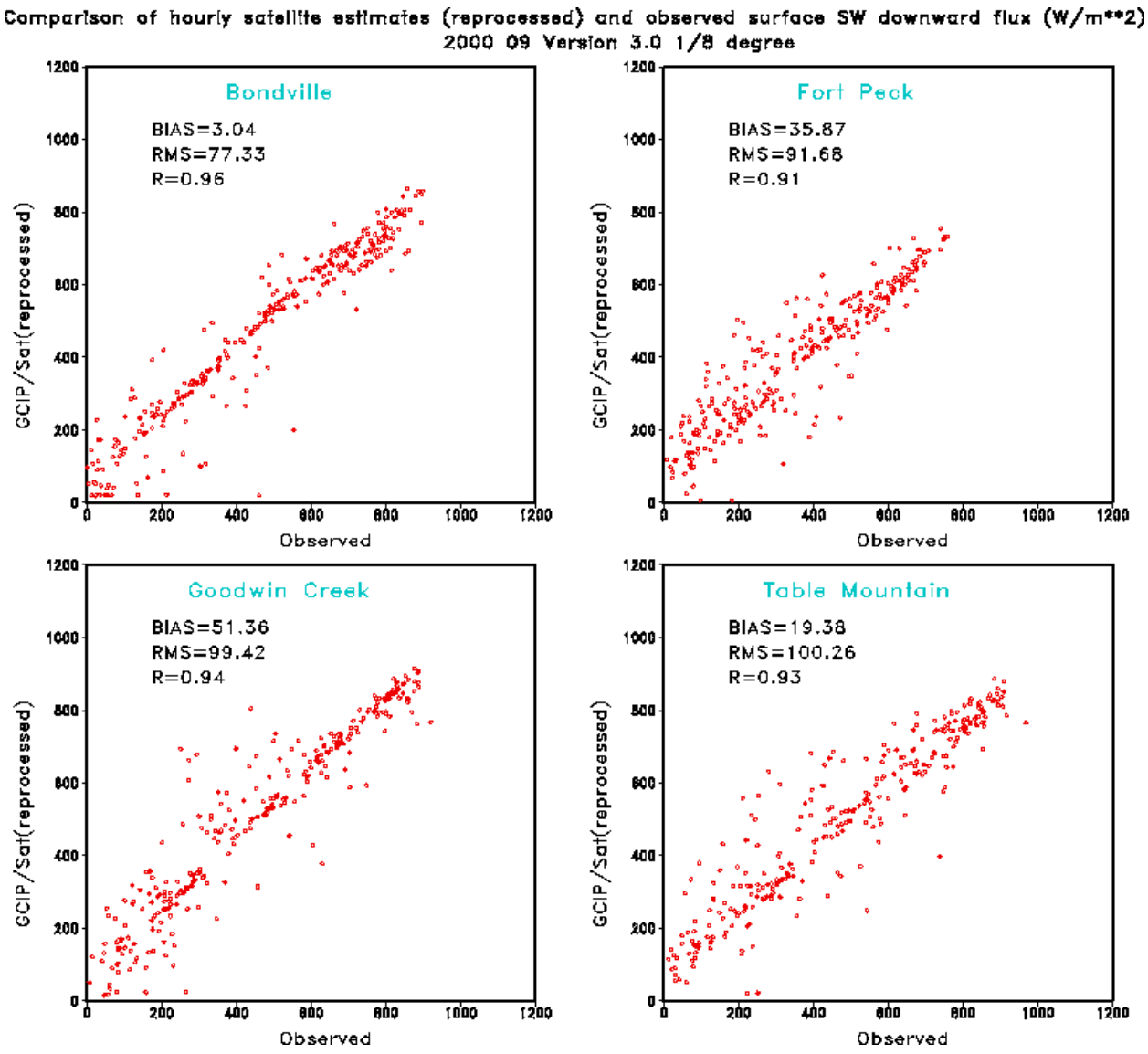

Figure 4. Comparison of hourly data for satellite estimated and observed surface downward SW fluxes for August 2000 at four SURFRAD sites.

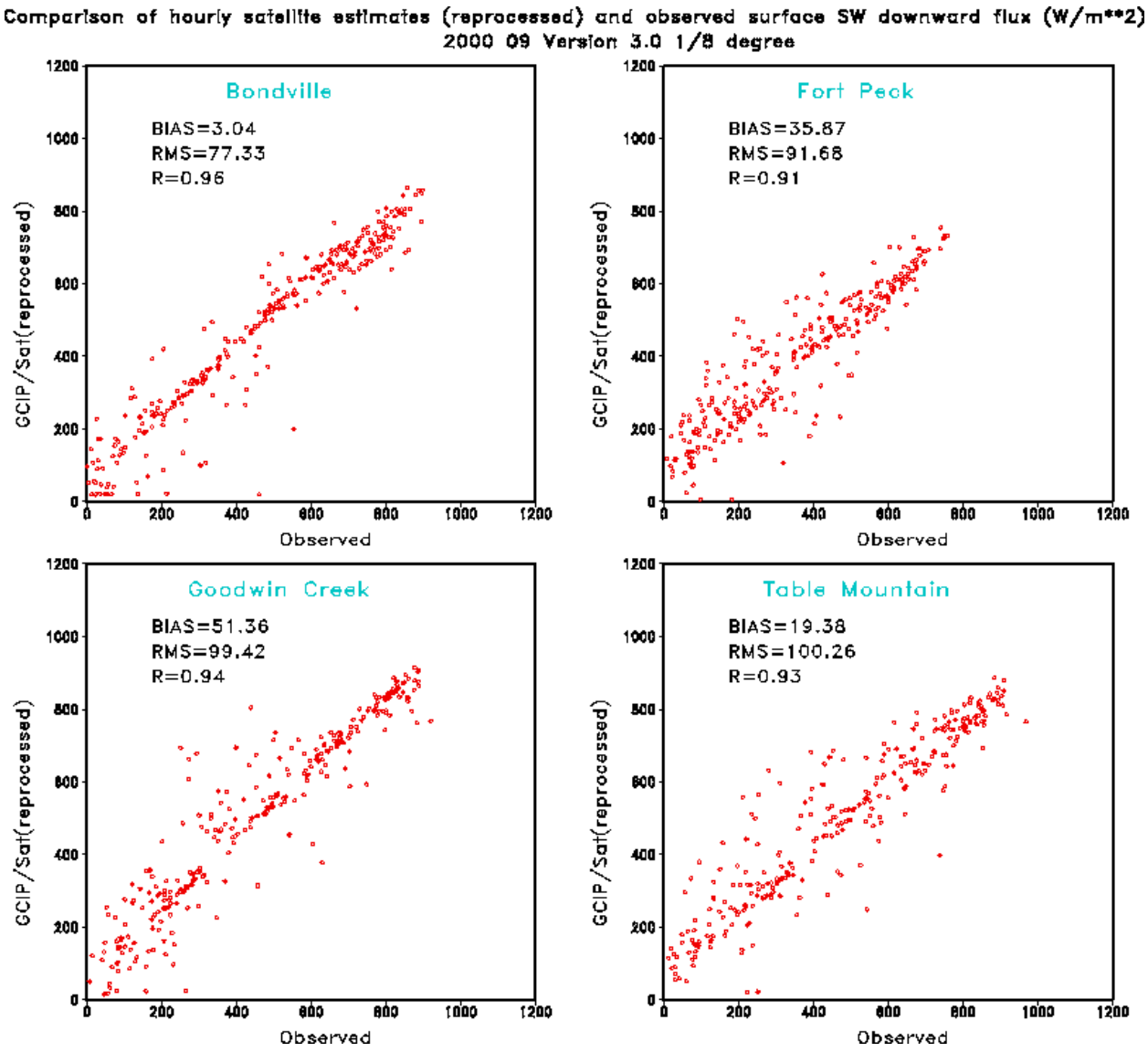

Figure 5. Comparison of hourly data for satellite estimated and observed surface downward SW fluxes for September 2000 at four SURFRAD sites.

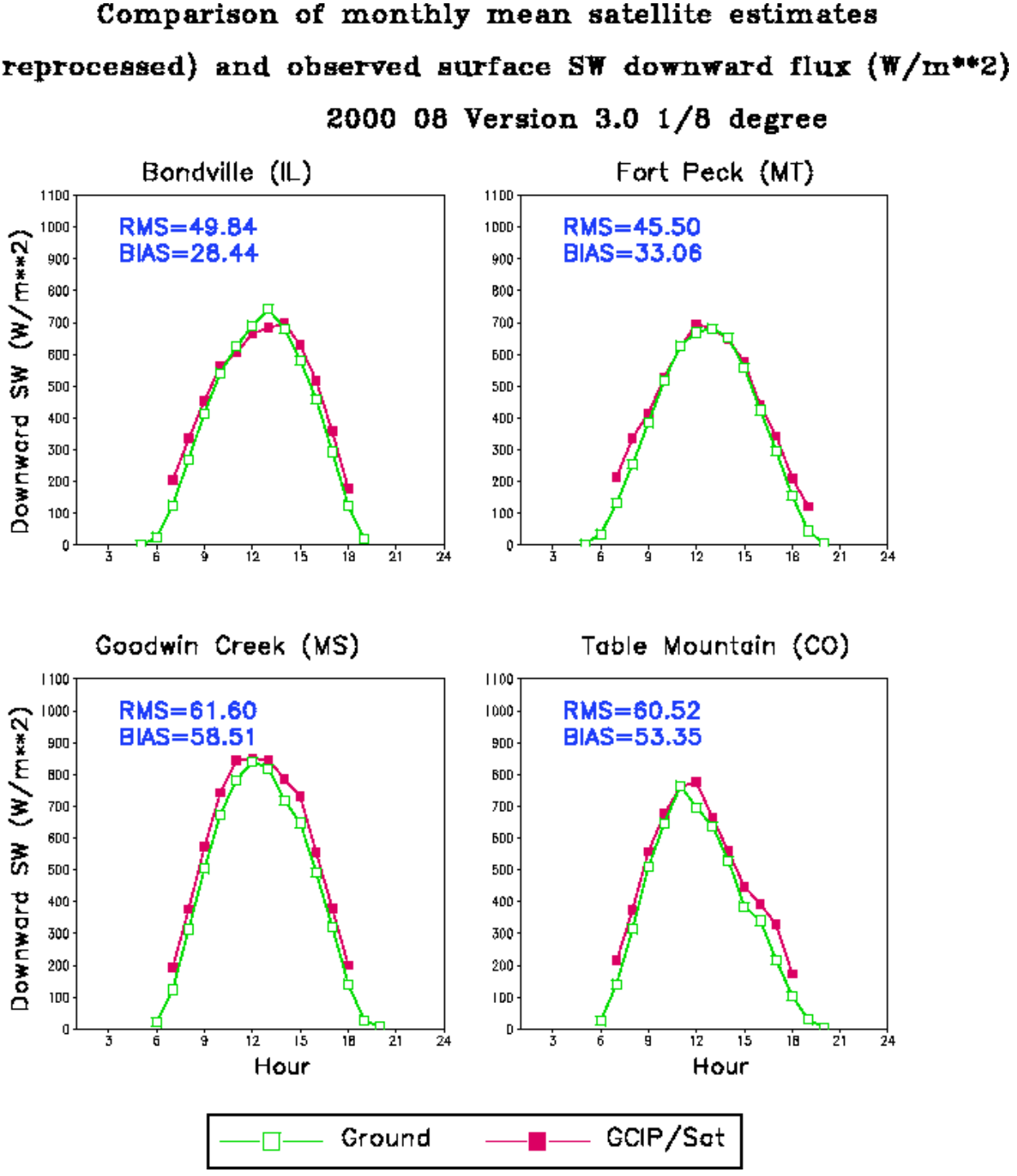

Figure 6. Comparison of monthly mean diurnal profiles of satellite estimated and observed surface downward SW fluxes for August 2000 at four SURFRAD sites.

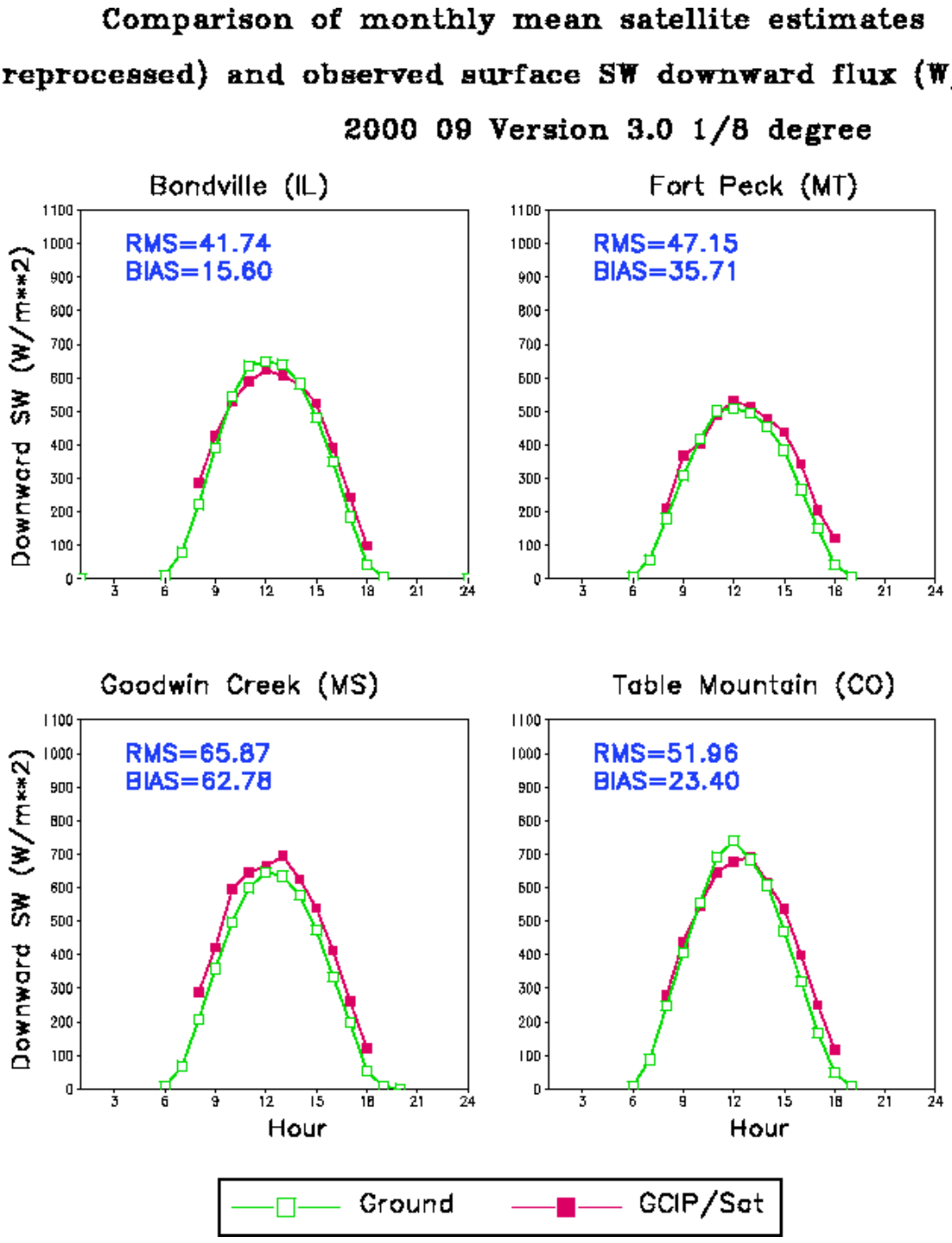

Figure 7. Comparison of monthly mean diurnal profiles of satellite estimated and observed surface downward SW fluxes for September 2000 at four SURFRAD sites.